THE CAPTIVE BREEDING OF COLUBRID SNAKES.

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A BRIEF HISTORY

In the last 3 to 4 years there has been a concentrated interest in the captive breeding of North and Central American colubrid snakes. This activity can now be found in the private, scientific, and institutional (zoo) realms of herpetology. The major genera of concentration for this series will be *Elaphe*, *Pituophis* and *Lampropeltis*.
There are four major reasons why these genera have been the chosen few. These are: 1) accessibility to wild populations to establish breeding stock; 2) ability for wild caught, as well as captive-born specimens, to adapt and perform well in captivity; 3) the beautiful colours and patterns that many species' groups exhibit; and 4) the commercial value of captive-born offspring.
In recent years many conservation laws have put strict limitations on the collecting of many species of snakes. Fortunately, many of the species in the genera *Elaphe*, *Pituophis* and *Lampropeltis* were well on their way in captive-breeding situations before these laws were initiated. Much of the original parentage was collected in the field between 4 to 8 years ago. The species that people were interested in were usually caught within 1000 miles (often much less) of home, and this created annual pilgrimages to the collecting grounds. Al-

most all of these species are relatively abundant and easily found in their native habitats. Whether or not these collected specimens would be used for captive breeding depended on the collector.
These three genera have been documented as early as the 1890's for their abilty to adapt to a captive lifestyle. The most common sign for this is their willingness to feed on the first or second day of captivity. Most specimens lock right into an annual breeding performance as manipulated by the keeper. Perhaps the most dramatic example of domestic adaption is the proven ability to raise a female captive-born hatchling to an adult which lays eggs at 18 months of age. The adult size of these snakes has also been significant as they require less cage space than larger constrictors. Anyone who begins to observe the wide variety of patterns and stark colours in the *Lampropeltis* or *Elaphe* groups can attest to the fact that they are among the most beautiful of snakes. Many captive breeders have selected certain snakes, such as the two phases of the Californian king snake, to experiment with pattern polychromatism. Very valuable data on behaviour, pattern types, and body morphology is being acquired that will perhaps redefine the now existing status of relationships within a genus and between genera. The favourite species among captive breeders are *Lampropeltis mexicana*, *Lampropeltis triangulum*, *Lampropeltis pyromelana*, and various amelanistic (a partial albino lacking black piment, Prüst, 1984) subspecies found in *Lampropeltis getulus*, *Pituophis melanoleucus*, and *Elaphe* spp. This is primarily due to the beautiful display of bright colours on light backgrounds or in ringed patterns.
The commercial sale of captive-produced offspring is becoming a bigger part of captive breeding. Many amateur herpetologists, as well as institutions, develop a taste for more expensive specimens. It makes sense to want to produce commercial-

ly salable offspring to offset the cost of the initial breeding stock. Many private individuals are looking to the years ahead when an actual profit can be made. In recent years there has been an ever-increasing value put on obtaining captive-produced offspring. The reason for this is threefold: 1) hatchling size is usually the only size obtainable; 2) a hatchling is almost guaranteed to be free of any internal parasites; and 3) the intrinsic conservation value of obtaining a captive hatchling rather than collecting it in the field.

ANNUAL CYCLES AND BREEDING TECHNIQUES

Until recently, little had been published on the actual implementation of captive-breeding theories and techniques. This article is intended to present in specific terms some of what is required to be successful in captive breeding. Let me point out that there can be many exceptions, but these methods have worked well for the mainstream of captive breeders.

First, the following assumptions must be made:

1) The sexes of breeding stock are known by the keeper and are of adult breeding size.
2) All breeding stock are of reasonably good health and have little or no parasites.
3) The keeper has a well established rodent-breeding colony or a ready source of rodents.
4) The keeper has a cage set-up suitable for the species with which he is working.

Let's use an arbitrary date of August 1st as the starting point. Between August 1st and December 1st the main concern is feeding. This time period is extremely important and may determine your success later. Females need to put on an excessive amount of body weight during this period before being cooled for the winter. Basically, you offer as much food to the females as they will take



Fig. 1. *Lampropeltis triangulum campbelli*. Foto: S. Osborne.



Fig. 2. Terraria kweekdieren / Breeding facilities. Foto: S. Osborne.

during this time. An every-seven-day feeding schedule is quite adequate. Adult specimens usually will eat several food items per feeding on this schedule and have adequate time for digestion before the next feeding. To get an idea of typical food requirements, it takes about 8-12 adult mice per month for an adult female albino corn snake (*Elaphe guttata*) or 12-15 fuzzy (10-day-old) mice per month for an adult female Greer's kingsnake (*Lampropeltis mexicana greeri*). It is very important to maintain a cage or substrate temperature of 24-28^{0}C throughout this 4-month period to allow for adequate digestion. Females store fat in the posterior portion of their body that is later critical when forming eggs. Male specimens generally desire less food than an equivalent-size female and do not store as much fat. It is important to get body weight on the males as well, as they may not eat at all during the breeding season. Hopefully, by December 1st, the females will have enough body weight to later produce a maximum number of fertile eggs for their size.

Between December 1st and March 1st a cooling period seems necessary to initiate physiological changes in both sexes. This sets the groundwork for development of eggs and maturation of sperm when warming begins. The cooling temperature should remain between 13-18^{0}C throughout this 3-month period. Males and females should be in separate cages starting on December 1st. No feeding is done during this 3-month period but water must be provided.

There has been a great deal of argument as to whether light cycles affect reproductive success in snakes. I believe the only essential criteria to initiate reproductive activity is a cooling followed by a warming period. For the purposes of not excluding anything, however, the following is a list of light-cycle methods that have been successful:

1) On March 1st, 13 hours of cage or room light per day increasing 20 minutes per week thereafter ending at 16 hours of cage or room light per day on April 30th. No sunlight is allowed into the room.
2) Natural sunlight allowed into the room on a year-round basis with incandescent light or heat tape used when heat is required to maintain correct temperatures.
3) Twenty-four hours of light per day all year round even during the cooling period.

However, it has yet to be proven conclusively that lightcycles influence reproduction in these genera although breeders still use artificial light cycles.
Aside from lighting, between March 1st and August 1st is the time to concentrate on captive breeding. The best feeding response of the entire year usually takes place throughout March and into early April. This is again an extremely important time for fattening of the breeding colony. The snakes can begin feeding within 24 hours of their initial warming on March 1st. It is important to raise the cage temperature to about 28°C at some point each day but also allow it to drop to 24°C each day. This allows for adequate food digestion and also the ability to get away from prolonged heat. A constant, 24-hour per day cage temperature of 28°C or above may cause sterility of males in certain species. A good behavioural cue that the snakes are too warm too long is if most of the males continually stay as far away from the heat source as possible (i.e., right up against the glass). Providing a cage thermal gradient is the best way of insuring adequate, but not excessive, heating. In this way the snakes can select their own temperature preference.
Specimens that respond well to feeding will usually shed soon after March 1st. For *Elaphe* and *Lam-*

propeltis species, the first shed usually occurs between March 20th -31st. For *Pituophis*, the first shed normally occurs between March 23rd-April 4th. Although these shed dates do not apply to every specimen, there seems to be a trend toward this occurrence. The first shed gives the keeper an idea as to how close the females are to full follicle (unfertilized egg) development. Females appear to reach maximum reproductive receptivity from 3 to 14 days after this first shed. The easiest way to determine if a female is reproductively active is to introduce her into the male's cage. If, upon body contact with the male, the female violently flips her tail, bunches up her body, or constantly tries to stay away from the male, she probably is not ready. Under these circumstances, the male may try to overpower the female or rapidly loose interest. However, if the female responds by slowly crawling around the cage stretched out, allowing the male to crawl on her back, and lifting her tail to expose the cloaca, she is ready. To ensure a viable mating to a female that responds positively, it is best to reintroduce a male at least 2 more times, several days apart. At some point in early egg development, the gravid female will begin to show the negative response to the presence of the courting male.

Females will continue to feed for several weeks into pregnancy but generally stop eating during the last 3 weeks before egg laying. Internal development of the eggs after mating normally takes between 28 and 45 days, depending on the individual and the mean cage temperature during this period. Another shedding occurs toward the end of pregnancy. Females will shed approximately 7-12 days prior to egg laying. This is an important cue in preparing a suitable egg-laying location and also for knowing approximately when the eggs will be laid.

Most of the egg laying will take place in the

month of May with some species (e.g. *Lampropeltis triangulum sinaloae*) laying slightly later. As soon as egg laying takes place, most females will feed heavily to regain body weight. It is possible to perform a second mating at this time. If a female has good body weight after the first egg laying, she may rapidly develop new follicles. It is apparently important to keep the male and female together constantly immediately after the first egg laying to ensure a second reproductive success. This is in contrast to the male-female introduction-separation method for the first mating. If a female does produce a second clutch, she will follow the same incubation-shed pattern as for her first clutch. Most second clutches are smaller than the first, and are laid in middle to late July.
In summary, the following is recommended:

1) Heavy feeding of females and males at all times of year except in the cooling period and the latter part of pregnancy.
2) A cooling period of approximately 3 months at temperatures between 13-18^{0}C.
3) Separation of the males and females during the cooling period.
4) At all times except during the cooling period, maintain a cage or substrate temperature of 24-28^{0}C, allowing the temperature to rise and fall within this range each day.
5) Introduction of females into the male's cage when full follicle development is suspected - watch for positive female reaction.
6) Observation of shed dates in relation to follicle development or egg-laying date.

PREPARING FOR EGG LAYING AND HATCHING OF EGGS

As stated before, females will usually undergo a pre-oviposition shed shortly before egg laying.

On the day this occurs, it is important to provide a suitable egg-laying site that the female will be satisfied with. A successful way to accomplish this is to use moist sphagnum or peat moss as a substrate inside a container. Typical containers would be tupperware or a large butter dish with an entrance hole cut in the top or side large enough for easy passage. Two to three inches of substrate with ample room for the snake to move around determines the container size.

An occurrence that is often distressing to the keeper is the excited activity some females exhibit several days prior to egg laying. This might be referred to as "nesting search" and is a normal behaviour. This behaviour is characterized by movement in and out of the egg-laying container and all around the cage. At the point when egg laying is due, the female will normally settle down in the container and lay her eggs. It is important to remove the water dish from the cage shortly before the egg-laying date as females may choose this as an alternative egg-laying site, which can result in drowning of the eggs.

At the time when egg laying occurs, females deposit eggs that often connect to each other via a bonding substance that coats the outside of each egg. If the eggs are found soon after being laid (e.g., 30 minutes), it is possible to separate them. This procedure is delicate and requires sensitive handling. The reason for doing this is mainly to separate possibly infertile eggs that may mold and possibly affect adjoining fertile ones. Fertile eggs generally appear bright white and firm rather than soft and discoloured. A clutch of infertile eggs is often laid earlier than expected following the pre-oviposition shed, and the eggs are often not all laid in the same 24-hour period. If the eggs are solidly connected to each other, it is best to leave them that way. Eggs in the wild hatch in this manner, and they are easily



Fig. 3. *Lampropeltis getulus californiae*, albino.
Foto: S. Osborne.



Fig. 4. *Lampropeltis getulus californiae*, albino.
Foto: S. Osborne.

hatched this way in captivity.
Before egg laying occurs, an incubation container should be ready in order to set up the eggs as soon as they are laid. An ideal incubation substrate is vermiculite moistened with water. The recommended ratio is 1:1 (vermiculite to water) by weight (1 cup vermiculite/20 ml water). Plastic shoe or sweater boxes have proven to be excellent incubating containers. The specifics for the setup are

1) Plastic shoe or sweater box with lid;
2) A 5-7 cm layer of moistened vermiculite in box;
3) A 3 mm hole drilled in opposite ends of the box for ventilation (otherwise it is a closed system, which could lead to embryo asphyxiation);
4) Single eggs or the entire clutch partly buried in the vermiculite with 1/3 to 1/2 of each egg exposed;
5) Light misting with water every 2-3 weeks or as needed to maintain the original vermiculite-to-water ratio.

The final and most important aspect of incubation is temperature. For these three genera, a constant temperature of 26-28^{0}C seems ideal. Temperatures over 30^{0}C should be carefully avoided. Eggs incubated as low as 18-21^{0}C will hatch successfully but take more time. Average hatching times for a few species are

Lampropeltis getulus	60-65 days
Lampropeltis triangulum	60-65 days
Lampropeltis mexicana ssp.	55-65 days
Elaphe guttata and *Elaphe obsoleta*	55-65 days
Pituophis melanoleucus ssp.	68-75 days.

Approximately 2 days can be added for every 0.55^{0}C that the average incubation temperature falls below 26^{0}C (e.g., 70-75 days for *Lampropeltis getulus* at 24^{0}C). A table or shelf serves as a suit-

able location to keep the eggs if the temperature there stays within the 18-28^{0}C.
Usually all initial slitting of the eggs by the hatching snakes takes place within a 48-hour period. Once the egg is slit, 12-48 hours may pass before the hatchling emerges.
I have found that the most satisfying and enjoy - able time in captive breeding is when the eggs hatch. It tells you that your captive breeders are performing to their best potential in your breeding situation.

RAISING OF HATCHLINGS TO ADULT BREEDING SIZE

In the last 3-4 years, it has been found that the reproductive capability of these genera is a function of size and not age. It was thought by several leading herpetologists in the field that it required a minimum of 3-4 years of age before these snakes became reproductively active. However, due to recent methods of advanced husbandry, it has been determined that males can be successfully mating as early as 9 months of age end females as early as 18 months of age with viable offspring resulting from these matings. In order to achieve this, it is necessary to maintain a strict feeding schedule in addition to various feeding techniques for various species. For rapid growth it is necessary for a continuous feeding schedule - as often as the snake will eat. Increasingly large food items should be offered as the snake can handle them. Generally, this schedule requires pinkies or fuzzy mice every 2 days for the first 5-6 months and to be interrupted only by the shed phase. Since there is little or no fur on the feed items, they are rapidly digested. From 6 months to adult size, feedings can be every 4-7 days with more food items per feeding. A good indication that the snake is growing rapidly is that skins are shed

every 21-30 days.
It takes approximately 80-100 individual feedings and about 14 months to reach adult size in females following this method. Males can successfully breed at much smaller sizes and may only require 8-10 months of this feeding schedule to reach breeding size. Whether or not the breeder desires to rapidly raise his hatchlings is a matter of choice. It requires a good deal of work and a substantial rodent colony. There has been some suggestion that "forcing" snakes in captivity to grow more rapidly than in the wild may cause detrimental health problems. However, there is no indication in the literature or among captive breeders of these snakes that this is true. At any rate, the following techniques could prove useful for anyone wishing to raise hatchlings.
The set-up that seems to be most successful is to provide each hatchling with the following:

1) A plastic shoe box (available in various department stores) with several 3 mm holes drilled through the top. The lid needs to be secured using heavy tape, etc. Most shoe boxes measure (lxwxh) 30x16x8 cm. This serves as the cage for the hatchling until about 12 months of age when it can be moved to a larger permanent cage. The main reason that plastic shoe boxes are used is that it provides easy access to the hatchling; a small confined area for the snake and its live food items; easy heating using a heat tape; and an inexpensive, compact cage source.
2) A flexible heat tape (Wrap-on Heat Tape Brand is available through plumbing stores) that can be wired through a dimmer switch and will allow the spot where it passes under the plastic shoe box to maintain a temperature of 26-32^{0}C. A shelf can be used to place the shoe boxes with the heat tape running under the middle section of each of the boxes.

3) A suitable substrate in the shoe box such as a sheet of newspaper, non-toxic pine shavings, sand, or gravel.
4) A butter dish with a hole cut in the top (or other small hide box) that can be placed in the shoe box directly over the spot where the heat tape runs under the box. This is of primary importance as the snake needs to spend most of its time directly over the heat tape area in order to rapidly digest food. The type of substrate that is optimum in the butter dish will be discussed in the species accounts below. Many of the species require constant humidity or moisture in the butter dish to inhibit water loss from the hatchling. Some specimens go for several months without drinking from a water dish under this set-up.
5) A water dish that can not be tipped over. It is important to keep the shoe box substrate relatively dry.

Various feeding preferences of different species have proven to be a challenge in some cases. The ideal food item for most keepers is usually laboratory mice or rats and that will be assumed here. Listed below by species are some of the feeding preferences of hatchlings, some methods of switching hatchlings over to lab mice or rats, and some ways of stimulating a stronger feeding response:

1) *Pituophis melanoleucus*, *Elaphe guttata* and *Elaphe obsoleta*: Increase size of live mice in early growth (pinkies to fuzzies to full grown mice) and later switch to rats when adult size is attained. Use moist peat or sphagnum moss in a butter dish for the first 6-8 months, then dry substrate after 8 months.
2) *Lampropeltis getulus* and *Lampropeltis calligaster*: Increase size of live mice throughout

growth from hatchling to adult size. Maintain dry substrate in the butter dish from birth to adult.

3) *Lampropeltis triangulum* ssp. (south of United States border): Increase size of live mice throughout growth. Use moist peat or sphagnum moss in the butter dish for the first 8-10 months, then dry substrate after 10 months.
4) *Lampropeltis mexicana*, *Lampropeltis pyromelana*, *Lampropeltis zonata*, and *Lampropeltis triangulum* (north of Mexican border): These can be the most challenging hatchlings to raise. Typically the natural food source in the wild is lizards of the genera *Sceloporus* and *Uta*. *Lampropeltis mexicana mexicana*, *Lampropeltis mexicana greeri*, and *Lampropeltis mexicana thayeri* seem to show a stronger tendency towards starting on mice in captivity than do *Lampropeltis mexicana blairi* and *Lampropeltis mexicana alterna*. Hatchlings that will start on live mice should be given increasingly large live mice throughout growth. If a hatchling refuses mice, then the following can be tried in order of listing:
   a) Rub or scent a pinkie on a sceloporine lizard before offering it to the hatchling.
   b) Offer a sceloporine lizard in whole or part following it with a pinkie as the snake is swallowing the lizard. Eventually the snake may pick up on either a scented mouse or unscented mouse.
   c) Offer the hatchling a wild-type pinkie (i.e. *Paramyscus*) following it with a lab mouse pinkie.
   d) Raise the hatchling to adult size solely on lizards.

Methods "a" and "b" will usually work within the first 4-6 months and will completely switch the hatchling to lab mice. The best thing to do is to continually offer the hatchling a lab mouse in the

event that it may decide to take it. All of the hatchlings in group 4 should be provided with moist peat or sphagnum moss in the butter dish for the first 8-10 months, then dry substrate after 10 months.

The main point to emphasize in raising hatchlings is to have the plastic shoe box - heat tape - butter dish set-up that will facilitate getting heat to the hatchling for food digestion. Once a snake is eating mice that are capable of harming it by biting, it is best to feed only pre-killed food. The hatchlings seem to prefer live pinkies and fuzzies as opposed to dead. If rapid growth is desired, then an abundant food source is necessary. If one method of feeding does not work on the more difficult species, then do not hesitate to try something else. Most of the methods presented in this article were derived by trial and error. There is the potential for even better husbandry approaches in the raising of hatchlings yet to be found.

REFERENCES

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